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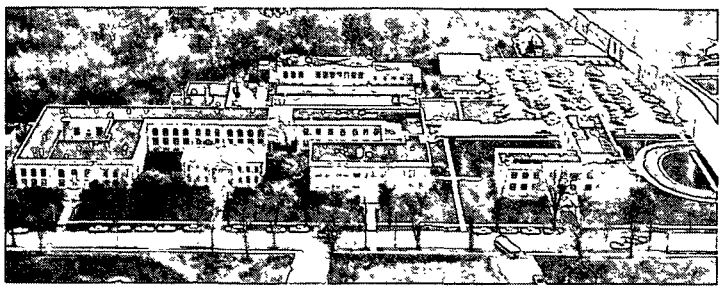

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GROWTH AND SURVIVAL OF HYBRID POPLAR AND *POPULUS DELTOIDES* CLONES IN EAST CENTRAL WISCONSIN

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GROWTH AND SURVIVAL OF HYBRID POPLAR AND POPULUS DELTOIDES CLONES IN EAST CENTRAL WISCONSIN

Gary W. Wyckoff[1], Dean W. Einspahr, and Ronald J. Dinus

ABSTRACT

Seventeen year growth, survival, and disease incidence for 38 poplar clones from six organizations were evaluated. Heritability estimates for height, diameter, and bole cankers were calculated for clones with adequate replication. Broad sense heritability estimates were 0.46 for height, 0.26 for diameter, and 0.39 for bole canker incidence. Growth ranged from 27 to 58 feet in height and 3.4 to 8.1 inches dbh. Survival and percent bole cankers both ranged from 0 to 100%. A strong site influence on growth was noted.

KEYWORDS: Populus deltoides, P. x euramericana, hybrid poplar, growth, disease, heritability

INTRODUCTION

Research on the genetics of Populus species was initiated at The Institute of Paper Chemistry (IPC) in 1954. A wide variety of species and materials have since been secured and evaluated, including some from the Aigeiros and Tacamahaca Sections. Widespread interest in establishment and culture of hybrid poplars for biomass production prompted remeasurement of several plantings containing Populus deltoides Marsh., related species, and various hybrids.

Reported here are results from a 17-year-old clonal trial. Several of the 38 clones are well-known, but performance data for the majority are limited, especially through age 17 and from northern sites. In addition, a dramatic increase in incidence of canker diseases (caused by an organism or organisms such as Septoria musiva Pk. or Fusarium solani Mart.) was observed between ages 10 and 17. Growth and survival of individual clones and estimates of genetic parameters under such conditions should be of value to workers involved in intensive poplar culture.

MATERIALS AND METHODS

Stem cuttings of 38 clones were rooted and grown for one year at the IPC nursery near Greenville, WI. Thirty-six clones were provided by Dr. John Berbee from the University of Wisconsin Arboretum, and two were IPC selections (Table 1). The trial, established in 1970 on a typical cottonwood site (Popovich 1982, Barkley 1983) near Appleton, WI, consisted of a randomized block design with four replications. Each clone was represented by two rows of four cuttings in each replication. Spacing was 8 ft by 12 ft. Variation in cutting availability and quality limited the number of replications for some clones and prevented establishment of border rows around individual replications and around the entire planting.

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Table 1. Clone parentage and source.

Clone Identification	Source	Parentage
W-2	University of Wisconsin	P. deltoides
W-5		P. deltoides
W-105		P. deltoides
W-117		P. deltoides
W-126		P. deltoides
W-132		P. deltoides
W-136		P. deltoides
W-140		P. deltoides
W-1045		P. deltoides
W-1070		P. deltoides
H-416-F	Harvard University	P. deltoides
H-424		P. deltoides
H-551		P. deltoides
H-585		P. deltoides
H-665		P. deltoides
H-778		P. deltoides
H-1076		P. deltoides
H-1109		P. deltoides
H-1633		P. deltoides
H-1651		P. deltoides
*W-58		P. deltoides cv virginiana x P. balsamifera
NE-32	Northeast Forest Experiment Station	P. angulata x P. berolinensis
NE-35		P. angulata x P. platierensis
NE-225		P. deltoides cv 'virginiana' x P. caudina
NE-238		P. deltoides cv virginiana x P. nigra cv 'volga'
NE-244		P. angulata x P. deltoides cv 'virginiana'
NE-265		P. angulata x P. nigra cv 'volga'
C-4	Ontario Department of Lands & Forests, Maple Ontario	P. x euramericana cv 'betulifolia'
C-5		P. x euramericana cv 'robusta'
C-14		P. x euramericana cv 'erecta'
IHAM, C-444		P. x canadensis
IH-78B, C-445		P. x euramericana cv 'Jacometti 78B'
IH-30A, C-450		P. x canadensis
*W-85		P. x canadensis cv 'charkowiensis'
*W-87		P. x canadensis cv 'charkowiensis'
C-401		P. x euramericana cv 'gelrica'
DH-4-62	Institute of Paper Chemistry	P. x euramericana
DH-9-62	Ontario Paper Co. & Institute of Paper Chemistry	P. x euramericana cv 'robusta raverdeau'

*Dr. John Berbee's number, University of Wisconsin.

Soils at the site are in the Manawa Series, which are fine, mixed, mesic Aquollic Hapludalfs (Barndt et al. 1978), and best described as silty clay loams with high fertility and moderate organic matter content (Table 2). Rainfall averages 30.8 inches annually, with 20.7 inches occurring between April and September.

Replications were arranged to account for apparent slope and soil moisture gradients. Two replications were located on the higher and somewhat drier portion of the site, another on the more sloping section, and the last at the lower, flatter, and wetter end of the trial.

Table 2. Soil texture and nutrient analysis.

Sample Depth	pH	Organic Matter, tons/acre	Lbs/Acre N	P	K	Ca	Mg	Texture
0-6"	6.7	60	4282	44	180	9500	1400	Silt loam
6-12"	6.8	34	2428	20	175	7500	1400	Silty clay loam
12-18"	6.8	18	1286	9	215	6650	1500	Clay

The site had been planted to corn for the two seasons before planting. Site preparation consisted of disking, and the rooted cuttings were hand-planted. Maintenance involved rototilling the first three years after planting, and periodic mowing thereafter.

Survival, general condition, and total height were measured 1, 3, 5, 10, and 17 years after planting. DBH was measured at the end of the third growing season and in each measurement year thereafter. Bole cankers were first observed during the fifth growing season, and incidence was recorded in years 10 and 17. Relative volumes were computed as D^2H to reflect potential productivity at 10 and 17 years.

Imbalance prevented meaningful statistical analyses of all 38 clones. To quantify clonal differences and genetic parameters, analyses of variance therefore involved only those 20 clones that were adequately represented in three replications. Data from the lowest lying replication were excluded.

Analyses of growth parameters were also restricted to those four trees per clone per replication that were tallest at age 17. This method was adopted to offset the effects that cutting and rooting quality had on early growth of many ramets and clones, and more realistically represent the potential of individual clones. The goal was to evaluate a representative sample of material that most likely was all in good and equal condition at planting. Some upward bias undoubtedly occurred as a result, but rather few measurement trees were from the edge of the planting or from openings within it. Relative differences among clones thus appear quite realistic.

Analyses of survival data, in contrast, were based on all trees alive at each measurement date, and those of disease incidence include all trees ever cankered, whether dead or alive.

An analysis of variance (ANOVA) computer program for randomized blocks with subsamples (the model assumed fixed replication and clone effects) was used to evaluate differences between clones and calculate variances required for heritability estimates. Analyses of variance took two forms, one for growth traits when subsamples were used (Table 3), and the second for percentages of surviving and cankered trees per replication (Table 4).

Table 3. ANOVA for growth traits based upon 20 clones, 3 replications, and 4 tallest trees/replication.

Source of Variation	Degrees of Freedom[a]	Mean Square	Parameter Estimated
Blocks (b)	b-1	2	1153	--
Clones (c)	c-1	19	265	$\sigma^2 + n\sigma_e^2 + nb\sigma_c^2$
Experimental Error	(b-1) · (c-1)	38	60	$\sigma^2 + n\sigma_e^2$
Sampling Error	c · b · (n-1)	180	6.2	σ^2

[a] b = no. of blocks, c = no. of clones, and n = no. of subsample/replication.

Table 4. ANOVA for percent survival and canker incidence based upon 20 clones, 3 replications, and replication averages.

Source of Variation	Degrees of Freedom[a]	Mean Square	Parameter Estimated
Blocks (b)	b-1	2	1629	--
Clones (c)	c-1	19	1599	$\sigma^2 + n\sigma_e^2 + nb\sigma_c^2$
Experimental Error	(b-1) · (c-1)	38	546	$\sigma^2 + n\sigma_e^2$

[a] b = no. of blocks, c = no. of clones, and n = no. of subsamples.

Broad sense heritability estimates were computed by comparing variation among clones (genetic component) with that within clones (environmental component):

$$H = \frac{V_c}{V + V_s + V_c}$$

where H is broad sense heritability, and

V_c = variance among clones

V_s = variance due to differences among subsamples

V = variance due to differences among replications.

In heritability calculations, σ_c^2 was used to estimate V_c, σ_e^2 to estimate V_s, and σ^2 to estimate V.

Differences among clonal means were assessed via Duncan's New Multiple Range Test. Simple phenotypic correlations among selected variables were determined using standard sums of squares procedures. All tests of significance were at the P = 0.05 level.

RESULTS AND DISCUSSION

Overall survival (Table 5) averaged 86 percent at the end of the 10th growing season. Several clones, e.g., H-1633, proved difficult to establish and had considerable early mortality, clearly reflecting the problems posed by cutting and rooting quality. By age 17, average survival had fallen to 67 percent, largely as a result of the dramatic increase in canker incidence. Most trees dying during this period were cankered, and many had been cankered at age 10.

Variation among clones in terms of survival was significant (data not shown), and several survived and grew well despite large increases in canker incidence. W-1070, the fastest growing clone according to the analyses of variance, averaged 96 percent survival at 10 years and lost only four percentage points between years 10 and 17 (Table 5). Its canker incidence, in contrast, rose from zero to 68 percent. Replication effects on survival were non-significant.

Variation in growth traits was considerable over all clones (Table 5), and significant among those examined in analyses of variance (Table 6). Despite the significant variability, few clones proved particularly better or worse than others. Height of the majority at 17 years exceeded 50 ft, and DBH typically was greater than 7 inches. Annual height growth averaged 3.7 ft through the 10th growing season, but dropped to 2.9 ft between ages 10 and 17. Similar patterns were noted for DBH and D^2H. Some portion of the decrease in annual growth rates can be explained by crown closure, but the considerable increase in canker incidence undoubtedly also played a role.

The fastest growing and most productive clone, W-1070, was of pure *P. deltoides* parentage (Tables 1 and 6). The slowest growing clone, W-58, was a hybrid cross involving *P. balsamifera*, and was the most severely cankered entry at both 10 and 17 years. Aside from a few observations such as the above, no clear or consistent pattern between parentage and growth was apparent.

Table 5. Overall survival, growth, and canker incidence of P. deltoides and hybrid poplar clones.

	Age 10				Age 17			
Clone	Total Ht. Ft.	DBH, inches	% Bole Canker	% Survival	Total Ht. Ft.	DBH, inches	% Bole Canker	% Survival
IH-30A	46	5.9	6	100	58	8.0	100	94
W-1070[1]	42	5.3	0	96	58	7.4	68	92
W-132	44	5.6	10	91	57	7.6	86	84
C-5	41	5.2	10	90	57	7.3	89	88
NE-238	41	5.6	23	97	56	7.6	96	53
W-87	33	5.6	3	94	56	7.4	96	91
W-1045	42	5.2	12	100	56	7.0	90	88
C-401	40	4.9	7	91	55	7.8	82	47
H-1076	43	5.5	0	97	55	7.4	97	97
W-136	41	5.1	0	94	55	7.0	96	91
H-585	41	4.9	3	94	55	6.9	96	88
NE-265	37	4.0	0	94	55	6.6	37	85
IH-78B	42	5.9	0	97	54	8.1	46	72
DH-9-62	44	5.7	19	97	54	7.5	92	59
DH-4-62	44	5.3	6	100	54	7.0	100	100
W-5	39	5.6	7	94	53	8.0	83	91
H-1651	40	5.5	0	88	53	7.7	100	82
W-117	39	4.7	0	97	53	6.8	79	91
W-2	38	4.6	0	69	53	6.6	58	60
H-665	38	5.0	12	79	51	7.4	100	78
NE-225[1]	36	5.0	28	84	51	6.9	94	54
W-140[2]	38	4.2	0	82	51	5.8	100	68
IHAM	35	4.4	24	78	50	7.3	64	44
NE-35	37	4.8	12	100	49	6.4	97	97
W-126[1]	34	3.8	0	75	49	5.4	69	67
NE-32[1]	35	4.5	14	92	47	6.7	100	58
W-105[3]	30	3.2	0	75	46	5.6	100	62
H-778	33	4.1	0	92	45	5.5	0	63
C-4[3]	32	3.6	0	50	44	6.0	100	50
H-551	34	5.1	0	78	42	6.6	32	69
W-58	32	4.9	100	91	39	6.2	100	75
NE-244[2]	30	3.6	0	68	39	5.6	0	56
W-85	32	4.1	7	91	38	7.1	100	12
H-1109[3]	24	3.6	0	50	37	4.8	100	38
H-424[3]	32	3.5	0	100	37	4.1	0	75
H-1633[3]	17	2.3	0	50	27	3.4	0	25
H-416F[2]	25	3.3	0	63	--	--	0	0
C-14[1]	40	4.6	56	96	--	--	100	0

No superscript indicates data are averages of four replications.

[1]Data are averages of three replications.
[2]Data are averages of two replications.
[3]Data are averages of one replication.

Table 6. Means for growth traits at age 17 and canker incidence at ages 10 and 17 for the 20 clones examined in analyses of variance.[1]

Clone	Age 17 Height, feet	Age 17 DBH, inches	Age 17 D^2H	Age 17 % Bole Canker	Age 10 % Bole Canker
W-1070	62^{a}	8.3^{abc}	4274^{a}	70^{a}	0^{c}
W-87	59^{ab}	7.8^{abcde}	3661^{abcde}	95^{a}	4^{bc}
IH-30A	58^{ab}	7.4^{bcdefg}	3214^{abcdefg}	100^{a}	4^{bc}
W-132	57^{ab}	8.2^{abcd}	3829^{abcd}	87^{a}	4^{bc}
DH-4-62	57^{ab}	7.6^{abcdef}	3278^{abcdefg}	100^{a}	4^{bc}
C-5	57^{ab}	7.8^{abcde}	3514^{abcdef}	87^{a}	0^{c}
H-1076	57^{ab}	7.8^{abcde}	3596^{abcde}	96^{a}	0^{c}
W-136	56^{abc}	7.4^{bcdefg}	3048^{bcdefg}	94^{a}	0^{c}
H-585	56^{abc}	7.0^{defg}	2746^{defgh}	95^{a}	4^{bc}
W-1045	55^{abc}	7.1^{cdefg}	2811^{defg}	84^{a}	12^{b}
NE-265	55^{abc}	6.8^{efg}	2617^{defgh}	24^{b}	0^{c}
H-1651	55^{abc}	7.3^{bcdefg}	2876^{cdefg}	100^{a}	0^{c}
W-5	55^{abc}	7.6^{abcdef}	3223^{abcdefg}	79^{a}	8^{bc}
H-665	54^{bcd}	8.6^{ab}	4090^{ab}	100^{a}	4^{bc}
W-117	54^{bcd}	6.7^{efg}	2450^{efgh}	71^{a}	0^{c}
IH-78B	54^{bcd}	8.7^{a}	4042^{abc}	25^{b}	0^{c}
W-2	52^{bcd}	6.4^{fg}	2400^{fgh}	67^{a}	0^{c}
NE-35	49^{cd}	6.9^{efg}	2375^{fgh}	100^{a}	8^{bc}
NE-32	48^{d}	6.5^{fg}	2102^{gh}	100^{a}	13^{b}
W-58	40^{e}	6.3^{g}	1605^{h}	100^{a}	100^{a}

[1]Comparison of 4 tallest trees per replication from clones with 3 replications with the exception of bole canker where all trees were used.

abc...Duncan's New Multiple Range Test was calculated when "F" test values for treatments were significant. Values followed by a common superscript letter are not significantly different.

Replication effects on growth traits were also significant. Height growth was lower in replications at the higher and drier end of the planting (53 ft and 52 ft versus 59 ft), suggesting that many clones of the type included in this trial are sensitive to site conditions and perhaps not well-suited to more upland areas.

Pathogens responsible for the many bole cankers are not known with certainty, but the widespread cankering in this trial indicates that disease resistance must be considered in selection, breeding, and culture. The dramatic increase in incidence between ages 10 and 17 also underscores the need for long term testing. Most clones had little or no infection at age 10, but the greater majority had 90 or more percent infection at 17 years (Tables 5 and 6). Numerous cankers occurred in the upper portions of crowns and contributed to death and/or breakage of both branches and tops.

Variation among clones evaluated in analyses of variance was significant, with the best two being responsible for much of the variation (Table 6). These clones NE-265 and IH-78B, were both hybrids, with only one containing P. deltoides germplasm. In contrast, most clones having 90 percent or more infection after 17 growing seasons had P. deltoides in their pedigree. The most susceptible clone, W-58, was a P. deltoides x P. balsamifera hybrid, and extensive cankering undoubtedly contributed to the slow growth of this and similar clones. The impact of disease incidence on product quality and value are less easily determined, but may be as significant as or more so than those on survival and growth. Holt et al. (1981), for example, found that pulps from cankered trees had higher lignin content, more extractives, and less strength than those from trees free of disease.

Broad sense heritability estimates, as determined under the conditions of this experiment, indicate that height growth is under moderate to high genetic control (Table 7). A similar value was reported by Wilkinson (1973). Those for diameter growth were somewhat lower, but nevertheless sizeable and similar across ages. The estimates for D^2H at both ages 10 and 17 suggest that concurrent selection for height and DBH would lead to significant gains in volume productivity. Bole canker infection at age 17 also appears to be under moderate genetic control. The rather large estimate at age 10 (0.93) is inflated and unrealistic as a result of low infection levels. Variation among clones was maximal (0 to 100 percent) while that caused by other sources, especially within clones, was minimal. Such findings confirm that long term testing and uniform, heavy infection are essential for reliable estimates of clonal worth and genetic parameters.

Phenotypic correlations among growth traits were quite strong within and across ages (Table 8). Thus, the fastest growing clones at age 10 were among the tallest and most productive after 17 growing seasons. In addition, no relationship was found between growth at 10 years and disease incidence at either 10 or 17 years. The fastest growing clones were not necessarily more or less susceptible than others.

In sum, survival and growth of several clones in this experiment proved quite good, and a few of them may be useful for intensive culture and/or future breeding. Widespread susceptibility to cankering, however, indicates that disease must be considered in designing tests and making selections. The site

sensitivity of such materials was demonstrated by significant growth differences among replications. Thus, expected volume productivity and gains therein can be achieved only by close matching of planting material to site.

Table 7. Broad sense heritabilities for growth traits and canker incidence.[a]

Parameters	Age 10	Age 17
Total height (H)	0.31	0.46
DBH (D)	0.24	0.26
D^2H	0.43	0.42
% Trees with bole cankers	0.93[b]	0.39[b]

[a]Estimates based upon 20 clones, 3 replications, and 4 best trees per replication, except as noted.
[b]Estimate based upon 20 clones, 3 replications per clone and replication averages.

Table 8. Simple phenotypic correlations among traits within and across ages.

Factors	DBH Age 10	Height Age 10	D^2H Age 10	DBH Age 17	Height Age 17	D^2H Age 17	Canker, % Age 17
DBH - age 10	1	0.719	0.974	0.785	0.650	0.311	0.093
Ht. - age 10		1	0.818	0.457	0.758	0.353	0.104
D^2H - age 10			1	0.744	0.710	0.335	0.117
DBH - age 17				1	0.702	0.399	0.136
Ht. - age 17					1	0.406	0.123
D^2H - age 17						1	0.108
Canker % - age 17							1

Correlation coefficients - n = 96, $r_{0.05} = 0.203$, $r_{0.01} = 0.263$.

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